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FABRICATION AND STRUCTURAL ANALYSIS OF ALUMINIUM ALLOY (LM25) REINFORCED WITH SILICON CARBIDE AND GRAPHITE PARTICULATE

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ABSTRACT

Nowadays composite materials have become more popular for its wide range of applications and design flexibility, since the fuel costs are increasing day to day, most of the automobile industries are conducting various experiments to develop composites having less density and superior mechanical, tribological properties which are equally cost effective. In this case, we are using Silicon Carbide and Graphite. It is a compound of silicon and carbon with chemical formula SiC. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, Graphite is well known for its self-lubrication and thermal stability.

KEYWORDS: Silicon Carbide, Grains Of Silicon Carbide & Reinforced Aluminum

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Original Article

INTRODUCTION

Silicon carbide is a compound of silicon and carbon with chemical formula SiC. Grains of silicon carbide can be bonded together by sintering [5] to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. The first use of SiC was as an abrasive. This was followed by electronic applications. SiC also has a very low coefficient of thermal expansion 4.0×10^{-6}/K.

SiC is used[2] for its hardness in abrasive machining processes such as grinding, honing, water-jet cutting and sandblasting. Particles of silicon carbide are laminated to paper to create sandpapers and the grip tape on skateboards.

The mineral graphite is an allotrope of carbon. Unlike diamond (another carbon allotrope), graphite is an electrical conductor, a semimetal. It is, consequently, useful in such applications as arc lamp electrodes. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermochemistry as the standard state for defining the heat of formation of carbon compounds. Graphite may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel, because it is difficult to ignite.

Graphite and graphite powder are valued in industrial applications for their self-lubricating and dry lubricating properties. And hence, graphite may support SiC hardness by providing a layer self-lubrication between contact surfaces resulting in increase of wear resistance.

Aluminium LM25 Alloy: The chemical composition of Aluminium LM25 is as follows :

Table 1

Copper	0.1 max
Magnesium	0.2 – 0.6
Silicon	6.5-7.5
Iron	0.5 max
Manganese	0.3 max
Nickel	0.1 max
Zinc	0.1 max
Lead	0.1 max
Tin	0.05 max
Titanium	0.2 max
Aluminium	Remainder

SELECTION PROCEDURE

There were many advanced processes for producing metal matrix composites with discontinuous particulate reinforcement. Among all the processes, stir casting route by producing vortex in the crucible by means of mechanical stirring is the most suitable and cost effective method for producing larger components with homogeneous mixture of metal-ceramic particulates.

Most of the automobile components were produced by means of liquid metallurgy technique. This type of process is simple and cost effective technique of producing components. Stir casting is also one of the liquid metallurgy techniques for producing metal matrix composite.

SELECTION OF OPTIMAL COMPOSITION

It is obvious that the properties of the final composite depend on the optimal composition of the SiC and Graphite. According to various studies[1] conducted on Al-Gr MMC's, better properties were obtained up to 4% of Graphite in the Al matrix and the grain size of Graphite particulates varies from 40 to 150 microns based on process parameters.

It was observed that the conducted studies yield better properties of the composite were obtained on 7.5% w/w Sic in Al matrix. In this regard, SiC ranging from 5% to 7.5% w/w will be sufficient for the present work. By comparing[3] with similar ceramic particulates like SiC, Granite and alumina in various research works, the grain size of SiC particulates ranging from 50µm to 150µm may give better results.

Since a hybrid composite is going to be prepared, composition of reinforcements for obtaining better composite may differ from the results obtained from studies done with a single reinforcement. The resulting composite may show combined results of SiC and graphite. By studying Al-Graphite composites, it was observed that the graphite can be limited to 4% w/w and the SiC can be varied from 5% to 7.5% w/w with a step of 5%.

EXPERIMENTAL WORK

Construction of Stir Casting Furnace

In the present work, we require a stir casting furnace with 3 blade graphite stirrer. Since stir casting is not a conventional casting method we have to design a suitable one. Even though some stir casting furnaces are readily available in the market, a custom made conventional stir casting furnace is a lot cheaper and is best suited for the present work to vary process parameters according to the requirements.

A conventional stir casting furnace consists of the following basic components.

- Furnace
- Crucible
- Stirring Equipment

Preparation of Furnace

A furnace is prepared by using a cylindrical thick sheet metal drum. The inner wall of furnace is lined with refractory ceramic material to prevent heat losses and is sealed with glass wool material which is prepared from glass.

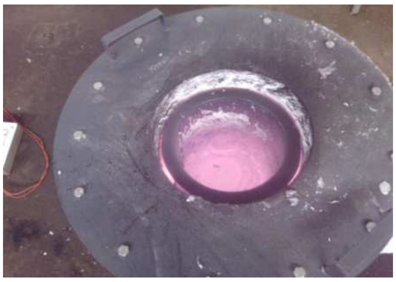

Figure 1: Stir Casting Furnace

Total furnace was made with kanthaal wire. It is applicable to produce heat up to 1350^{0}C. It is protected by 15mm thickness of ceramic material integrated with 5% of iron.

Preparation of Furnace Body

A furnace body is prepared by using different types of materials and sizes depend upon the requirement. Actual furnaces bodies are heavy and thick. In all types of furnaces, body is the main thing, it holds the total set up except temperature controller. So, it is very expensive and costly. In this process, preparation of the body is of less weight and less cost. It can withstand the high temperature. This type of furnace is easy to maintain, controllable and moving one place to another place is very easy, because it is low weight and convenient to move. The specifications of the furnace body are discussed below.

Figure 2: Preparation of Furnace Body

Temperature Controller

A temperature controller is used to control the temperature of the furnace by the help of heat sensor.

Figure 3: Temperature Controller

Temperature controllers are needed in any situation requiring a given temperature be kept stable. This can be in a situation where an object is required to be heated, cooled or both and to remain at the target temperature, regardless of the changing environment around it. There are two fundamental types of temperature control; open loop and closed loop control. Open loop is the most basic form and applies continuous heating/cooling with no regard for the actual temperature output. Closed loop control is far more sophisticated than open loop. In a closed loop application, the output temperature is constantly measured and adjusted to maintain a constant output at the desired temperature. Closed loop control is always conscious of the output signal and will feed this back into the control process.

Preparation of Stirrer

A 1200 rpm high torque reversible motor is taken and connected with a potentiometer for varying speeds as per the requirement. The motor shaft is coupled to a stainless steel rod and the other end is connected to a graphite three-blade impeller and is tested by stirring water in the crucible and grinded to the desired angle for producing vortex.

Figure 4: Stirrer with Potentiometer

Assembly of Stir Casting

Stir Casting is a liquid state method of composite materials fabrication, in which a discontinuous reinforcement is mixed with a molten matrix metal by means of mechanical stirring. The layout of conventional Stir Casting

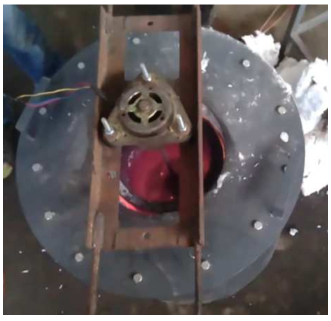

Figure 5: Stirrer with Furnace

At first, the matrix metal is melted in the crucible and then metal treatment (like degassing, fluxing, etc.) is carried out without stirring. Later, stirrer is inserted into the crucible and allowed to rotate the molten metal. Vortex is formed in the crucible due to the rotation of stirrer. Required quantity of reinforcement is preheated in a separate chamber and is gradually added to the vortex for uniform mixing of reinforcement into the matrix.

After the addition of reinforcement stirrer is removed from the crucible and the liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

Consumables and Miscellaneous Materials

A 15 litre silicon carbide crucible is bought for this purpose and is preheated to red hot condition (650^{0}C) to relieve from internal stress. A stand is prepared for mounting of stirrer assembly above the furnace. To avoid vibrations in the stirrer, motor is mounted on springs which damp the vibrations. A ceramic cap is used to prevent motor from exposing to direct heat from the furnace. The stand is made as such that some small adjustments can be made to centre the stirrer to the crucible.

Procurement of Raw Materials

As the project is carried at SIBAR Auto Parts Limited, Aluminium alloy is provided from the company's inventory which was used for the production of engine cylinder heads. Sic and Graphite are purchased from a chemist shop in Chennai and is also sieved for desired particle size.

Sample Preparation

A standard test bar die (Permanent mould) is borrowed from Sibar Auto Parts Ltd. which will produce 27 mm diameter cylindrical rod with large riser on it to avoid shrinkage. It was tested that the test bar casting consumes 1 kg of molten metal.

Metal is melted in a separate furnace and is transferred to the stir casting furnace using a standard ladle which will carry 1.5 kg of molten aluminium. The metal is maintained at 700^{o}C temperature in the stir casting furnace. A sample is taken with no reinforcements directly before transferring to the stir casting furnace.

At first molten aluminium of weight 4 kg is taken into the stir casting furnace. Graphite and SiC of4% and 5% by weight is measured separately and simultaneously preheated in separate containers on the furnace itself. When the temperatures in the furnace were settled nearly above 700^{o}C metal treatment is carried out by adding coverall to the molten metal which removes oxides and other impurities in the metal. Later, stirrer is inserted and allowed to rotate and create vortex in the crucible. The speed of the stirrer is controlled using a potentiometer to get desired vortex. After the desired speed is maintained in the crucible reinforcements were added slowly to the vortex and after completely adding the reinforcements the stirrer is further allowed to rotate for ten more minutes for uniform distribution of particulates.

After stirring, molten metal from the crucible is poured into the die cavity using a ladle and allowed to cure for about two minutes and removed from the die. The remaining metal in the crucible is also used for taking the test samples. The same procedure is followed for producing samples of 3% graphite and 6.5% SiC. All the samples were grouped and marked based on the composition of reinforcements and is sent to heat treatment process.

All the samples were fully heat treated which includes solution heat treatment for 12 hours at 520-530^{o}C and quenched in hot water followed by precipitation treatment of 8 hours at 170^{o}C

Figure 6: Samples after Casting

EXPERIMENTAL PROCEDURE

After heat treatment of samples the following operations were performed.

- Specimens were analyzed for variation in density as per Archimedes principle.
- Specimens were freed from the risers and turned to required dimensions on a lathe machine. Riser portions were shaped to rectangular sections and polished.
- Hardness test was conducted on the riser sections.
- Tensile test was conducted on turning samples with the help of a Universal testing machine. And average values of each composition were noted

RESULTS AND DISCUSSIONS

After heat treatment of all samples, each sample was separately tested for the density, hardness and tensile strength and the average values were analyzed by comparing with the zero sample. The results in various tests were discussed below.

For convenience of presentation and plotting, from here onwards pure LM-25 alloy samples were referred as **Group 0**, LM25 with 4% Graphite and 5% SIC samples were referred as **Group 1** and LM-25 with3% graphite and6.5% SIC samples were referred as **Group 2**

Tensile Strength

As it was the maximum stress that a material can withstand while being stretched, interfacial bonds may affect greatly on the tensile strength of the composite. In the below figure, we can see that the tensile strength was increased in the composites but doesn't have comparable variation. Weak interfacial bonds may result in a decrease in tensile strength of the composite, but here the increase of tensile strength shows that there was good interfacial strength. Since the reinforcements were preheated before mixing with aluminium there might be uniform distribution and smooth interface while mixing. From this result, we can expect good interfacial strength when we heat the reinforcements at higher temperatures, which will facilitate uniform distribution of more amount of composite without losing the strength.

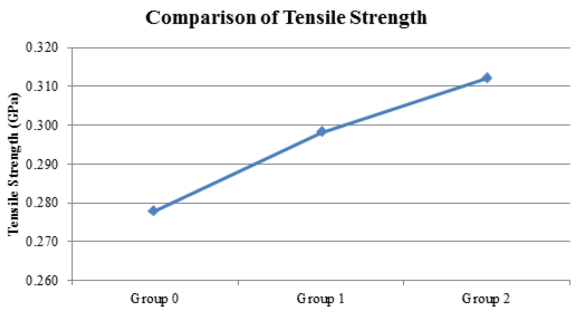

Figure 7: Variation of Tensile Strength with Different Composition of Aluminum, Graphite and Silicon Carbide

Where,

Group 0 = Pure Aluminium LM25

Group 1 = AL 25 + Graphite 4% + SIC 5%

Group 2 = AL 25 + Graphite 3% + SIC 6.5%

Modulus of Elasticity

Modulus of elasticity shows linear relation with tensile strength as same as conventional materials. In **Error! Reference source not found.** we can observe that the modulus of elasticity was increased but not greatly as same as tensile strength. The elongation of material is similar to the base alloy, almost negligible amount of elongation for all the groups. Since all the samples are fully heat treated, the samples will gain brittleness and hardness losing ductility which might be resulted in the tendency of brittle failure.

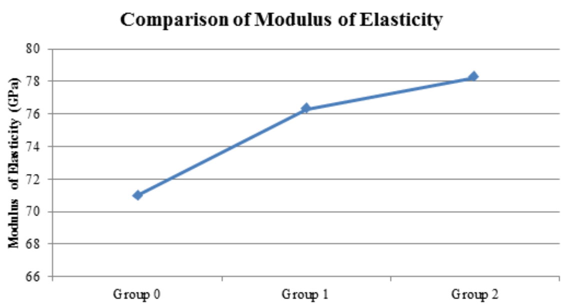

Figure 8: Variation of Modulus of Elasticity with Different Composition of Aluminum, Graphite and Silicon Carbide

Where,

Group 0 = Pure Aluminium LM25

Group 1 = AL 25 + Graphite 4% + SIC 5%

Group 2 = AL 25 + Graphite 3% + SIC 6.5%

Even though no particular wear tests were performed on the samples, while removing the risers on a band saw cutting machine some resistance was observed on both the composite samples.

Comparison of Total Deformation

It can be clearly observed in **Error! Reference source not found.** that for the given gas pressure the maximum

total deformation of the cylinder model gets decreasing with increase of SiC in the composite. But the decrease of total deformation is not varying linearly. The slope of the curve from Group 0 to Group 1 is steeper than the curve from Group 1 to Group 2.

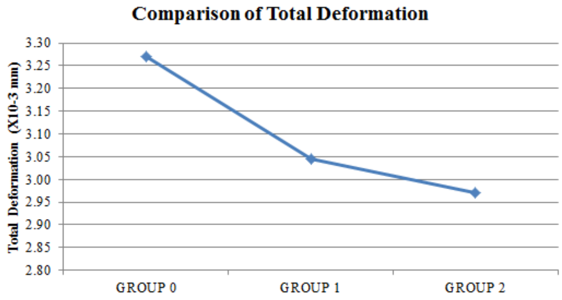

Figure 9: Variation of Deformation with Different Composition of Aluminum, Graphite and Silicon Carbide

Where,

Group 0 = Pure Aluminium LM25

Group 1 = AL 25 + Graphite 4% + SIC 5%

Group 2 = AL 25 + Graphite 3% + SIC 6.5%

Comparison of Strain

As the deformation is proportional to the strain, the maximum strain developed in the model seems similar to the comparison of total deformation.

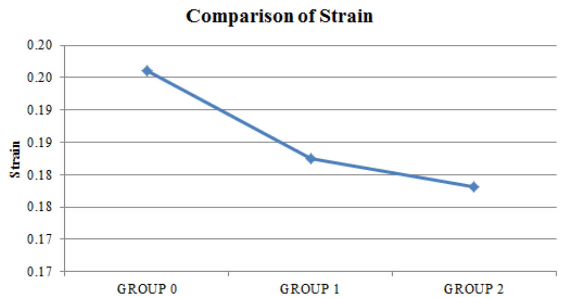

Figure 10: Variation of Tensile Strength with Different Composition of Aluminum, Graphite and Silicon Carbide

Where,

Group 0 = Pure Aluminium LM25

Group 1 = AL 25 + Graphite 4% + SIC 5%

Group 2 = AL 25 + Graphite 3% + SIC 6.5%

CONCLUSIONS

From the experimental and analysis of present work the following conclusions are drawn.

- Addition of SiC will increase the mechanical properties of the composite.
- By comparing with amount of SiC in the composite LM-25with 3% graphite and 6.5% SiC are most suitable for

the regular casting process.

- Hardness of the composite increased by 31.4% for 5% SiC and 42.5% for 7.5% SiC.
- It was noticed that the density of the composite is increasing with the increase of silicon carbide.
- From the analysis, the total deformation has been decreased by 6.9% for 5% SiC and 9.2% for 7.5% SiC. So, it can be concluded that this composite material in engine cylinders can be used for higher capacities than that of which they are now using.

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